LESSONS LEARNED FROM PERFORMING QUALITY CONTROL OF KSC LC-39B LIGHTNING PROTECTION TOWER METEOROLOGICAL DATA

John M. Orcutt – EV44 / Jacobs ESSSA Group
john.m.orcutt@nasa.gov
256.961.1790
NE-DOLWG
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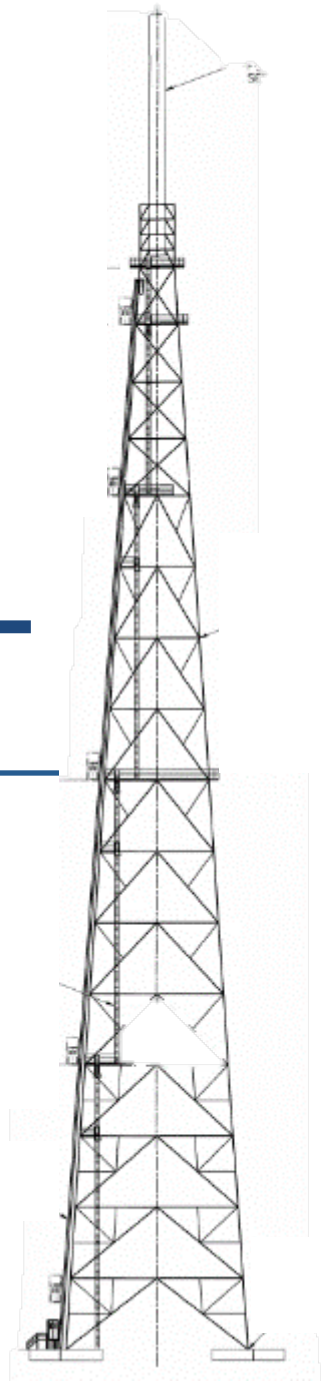

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Outline

- Introduction
- The QC process
- Lessons Learned

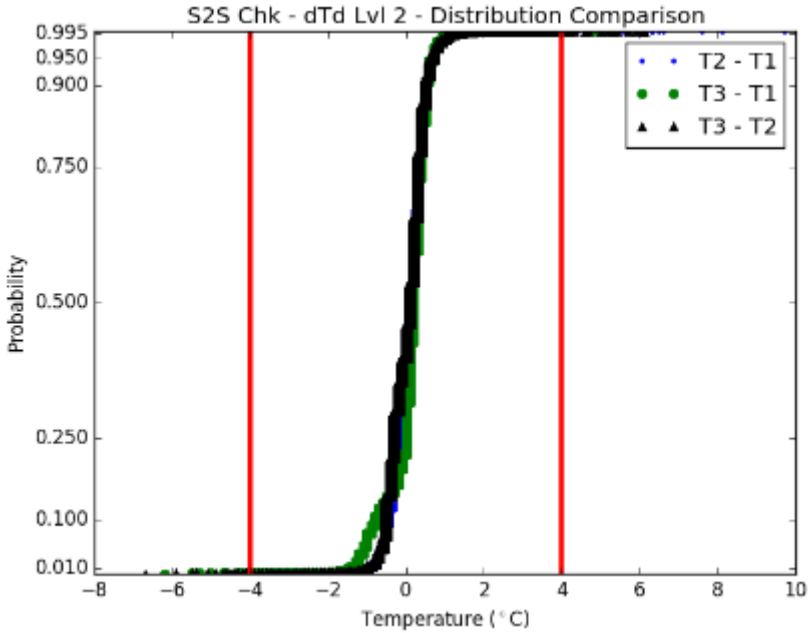
- Note: Not an all encompassing review of the QC procedures.

Introduction

- Located at LC-39B
- 3 towers, each with 4 heights
  - 40, 78, 116, 139 m (132, 257, 387, 457 ft.)
- T, RH, Td, mean and peak wind speed/direction are measured at each height.
- Data reported in 1 minute increments.
- POR of 2011 – April 2015.

The QC Process

- Based on previous work done by AMU and EV44.
- Individual Sensor Checks
  - Unrealistic Data Check
  - Tower Obstruction Check
  - Temporal Consistency Check
- Sensor-to-Sensor Checks
  - Data Hang-Up Check
  - Climatological Check
  - Horizontal Sensor-to-Sensor Check
  - Vertical Sensor-to-Sensor Check
- Up-Wind Tower Selection



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Lessons Learned

- QC process's intent is to keep only valid data, and remove only erroneous data.
  - Ideally, only an automated process would be used.
  - Many automated checks implement subjectively-derived thresholds as objective criteria.
  - Difficult to set a threshold that ensures removal of erroneous data while retaining all valid data.

Lessons Learned

- Manual QC is needed.
  - Examine distributions of a parameter to derive thresholds.
  - Investigate individual cases.
  - Example: Temporal Consistency Check
    - Removed valid data regardless of thresholds used.
    - Invalid data removed by this check was also removed by the sensor-to-sensor check.

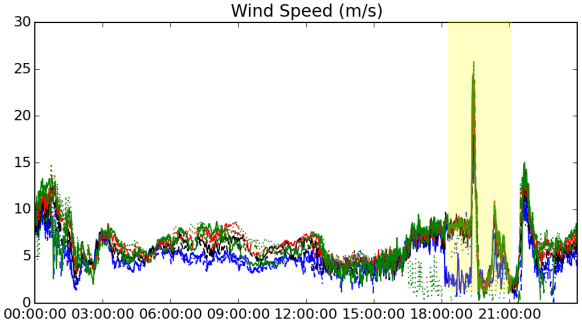
Example: Two Unique Cases

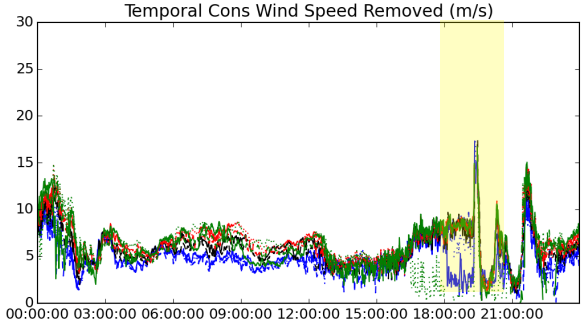
Initial Data

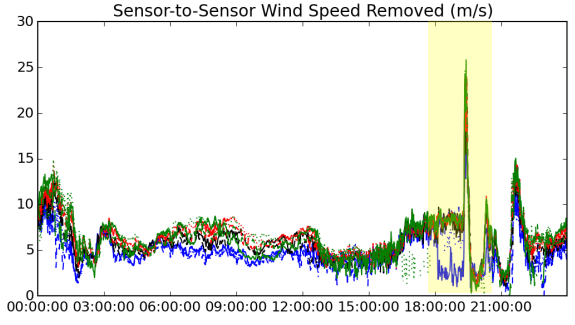
After Temporal Consistency Check

After Horizontal Sensor-to-Sensor Check

2011-05-14 00:00:00







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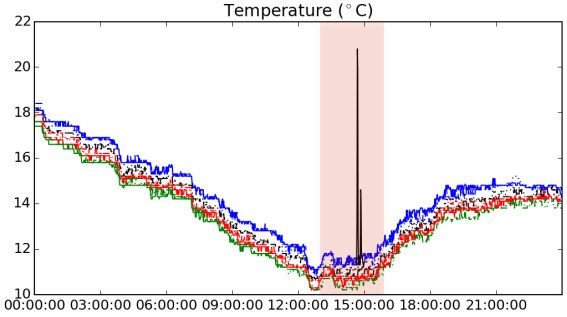

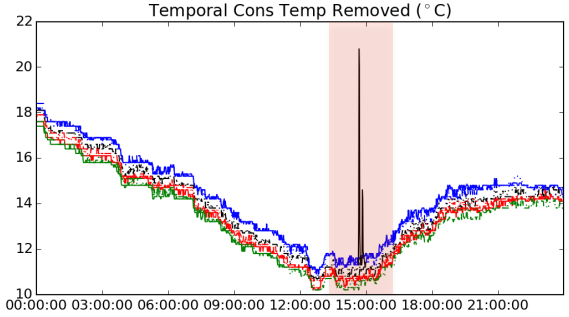

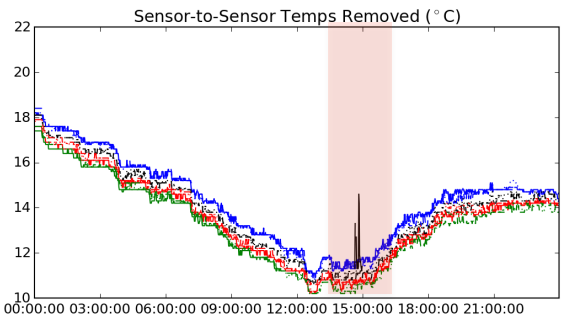

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Lessons Learned

- QC procedure for one database is not suitable for other databases.
- How do you determine a valid extreme event from an erroneous event?
  - QC process is often done months to years after data was recorded.
  - Possible improvements:
    - On the fly data flagging
    - Database of events
      - Watch/Warning Archive
      - SPC Damage Reports

Lessons Learned

- Even with including both automated and manual QC, one of two general philosophies must be followed.
  - Keep as much valid data as possible, but allow some erroneous data to exist.
  - Remove as much erroneous data as possible, but risk also removing valid data.

References:

- Barbré, R. E., “Quality Control Algorithms Used for the KSC Tower 313 Database”. Jacobs ESTS Group Analysis Report. ESTSG-FY08-1481. 2008.
- Decker, R. K., “Kennedy Space Center Launch Complex 39 Meteorological Databases”. NASA/MSFC/EV44. Presentation to the Space Shuttle Program Natural Environments Panel. 28 February 2008.
- Lambert, W. C., “Statistical Short-Range Guidance for Peak Wind Speed Forecasts on Kennedy Space Center / Cape Canaveral Air Force Station: Phase 1 Results”. NASA / Applied Meteorological Unit. NASA Contractor Report NASA/CR-2002-21180. 2002.
- Lubitz, W. D., “Effects of Tower Shadowing on Anemometer Data”. In proceedings of 11th Americas conference on Wind Engineering. 2008.

Acknowledgements

- James Brenton, BJ Barbre, Ryan Decker
  - Getting data, formatting data, finding more data
- EV44 T&PE Team

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Questions?

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Backup

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Unrealistic Data Check

- Data were removed if any of the following criteria were not met:
  - -26 ˚C < T < 40.5 ˚C
  - -18 ˚C < Td < 35.0 ˚C
  - Td < T
  - 0.0% ≤ RH ≤ 100.0%
  - 0.0 m/s ≤ Mean Wind Speed < 60.0 m/s
  - 0.0 m/s ≤ Peak Wind Speed < 69.5 m/s
  - 0˚ ≤ Wind Direction ≤ 360˚
  - Peak Wind Speed < Mean Wind Speed

Temporal Consistency Check

- The difference of a measurement from the mean of the surrounding hour was calculated
  - T measurements are flagged if $|\Delta T| \geq 4^{\circ}$ C & $|\Delta V| \leq 10$ m/s
  - Td measurements are flagged if $|\Delta Td|$ & $|\Delta T| \geq 4^{\circ}$ C & $|\Delta V| \leq 10$ m/s
  - WS measurements are flagged if the $|\Delta V|$ was ≥ 10 & $|\Delta T| \leq 4^{\circ}$ C

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Data Hang-Up Check

- Sensors reporting > 30 minutes of constant observations were flagged
- Flagged data were compared against other 2 sensors at the same level
  - T & Td were removed if magnitude of difference was > 0.3˚ C from either of the other towers
  - WS were removed if magnitude of difference was > 0.6 m/s from either of the other towers

Climatological Check

- Each T, Td, WS, & PWS observation was checked against the standard deviation for the given month and hour
  - T / Td were removed if the observation was outside of the mean ± 5 standard deviations
  - WS / PWS were removed if the observation was outside of the mean ± 10 standard deviations

Direct Sensor Comparison

- Each sensor was compared to the adjacent two sensors at the same height.
- Data were removed if the differences exceeded the following values:
  - $|\Delta T|, |\Delta Td| > 4.0$
  - $|\Delta RH| > 10$
  - $|\Delta WS| > 5.0$

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Vertical Consistency Check

- The mean wind vector differences and T differences were computed from the average parameter of the vertically adjacent sensors (both above and below)
  - Only done on the middle two sensors of each tower
- Data were removed if specific criteria were met, and the differences exceeded the following values:
  - $|\Delta WS| > 5.0$ **IF** the ΔWS from one of the other towers exceeds 3.0 m/s
  - $-1.5 < \Delta T < 2.5$ **IF** ΔT from one of the other towers exceeds 1.0 °C

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Up-Wind Tower Selection Criteria

- Was implemented on the mean wind if the mean WS is considered to not be “light and variable” (≥ 3.0 m/s)
- The mean wind direction must be within the following ranges:
  - 0° ≤ Tower 1 < 140°
  - 140° ≤ Tower 2 < 280°
  - 244° ≤ Tower 3 < 360°
- If the up-wind tower did not report, but the winds were within the overlapping up-wind sector from a down-wind tower, then the wind report from the down-wind tower was used.

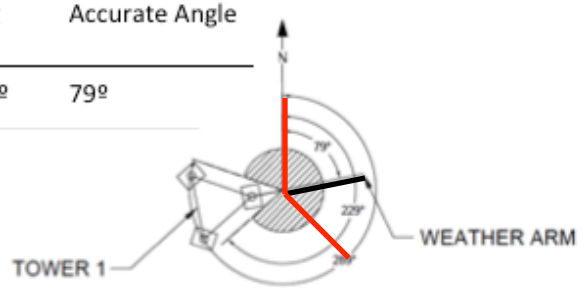
Up-Wind Tower Selection Criteria

- The most recent exclusive up-wind sensor is used if:
  - there were two towers that could be used as the up-wind sensor
  - there is only one sensor that reports
  - if the maximum wind speed does not exceed 3.0 m/s
- Shear Check was performed
  - Any wind speed measurement that had a wind shear value greater than 0.2 s^{-1} was removed
- T, TD, & RH of the up-wind tower are the mean values from all available towers at each timestamp and height.

Up-Wind Tower Conflicting Range

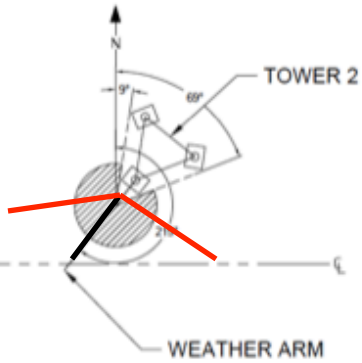
Lightning Protection Tower 1

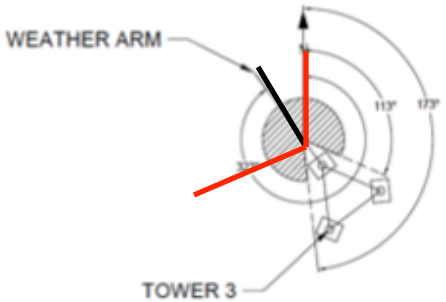
Conflicting Range	Accurate Angle
229º - 289º	79º



Lightning Protection Tower 2

Conflicting Range	Accurate Angle
9º - 69º	219º





Lightning Protection Tower 3

Conflicting Range	Accurate Angle
113º - 173º	323º

*Not to scale

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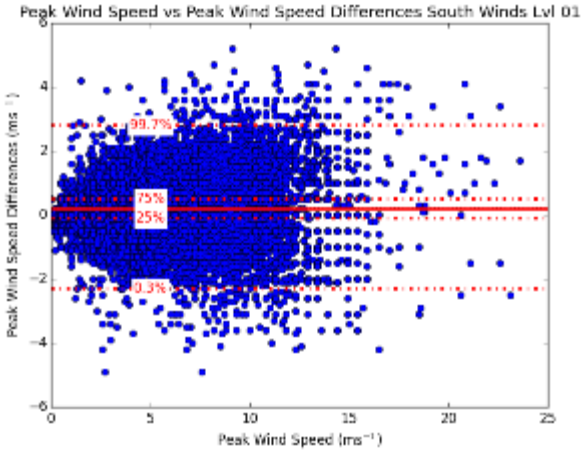
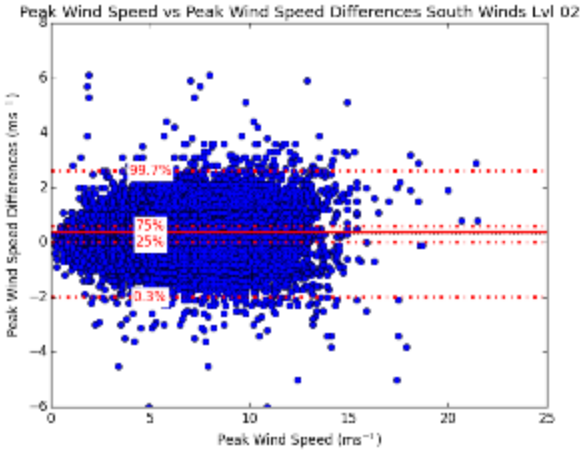
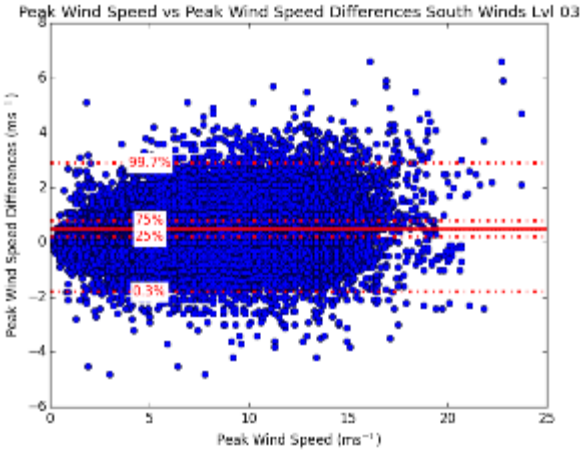
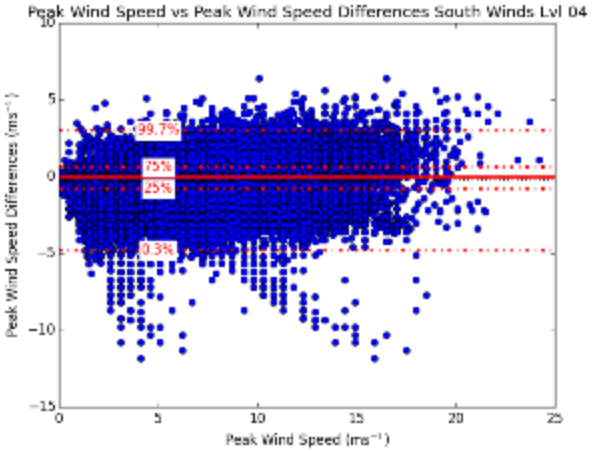
Control Case – Southerly Winds
T3 & T2 173º - 193º









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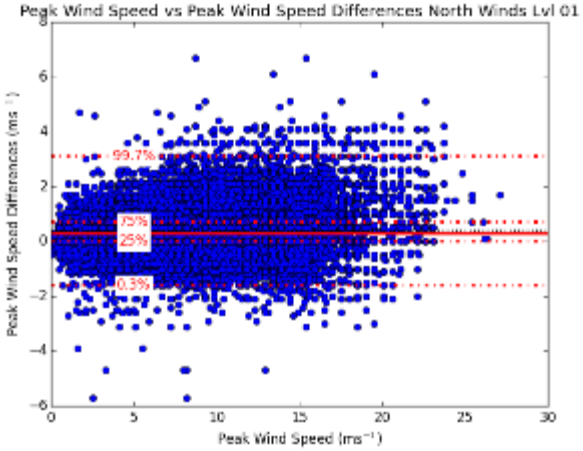
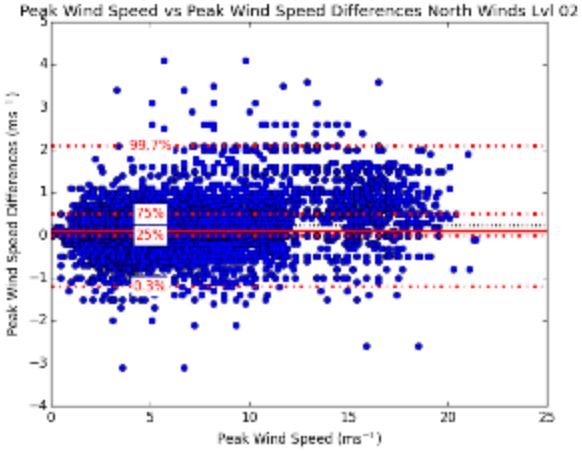
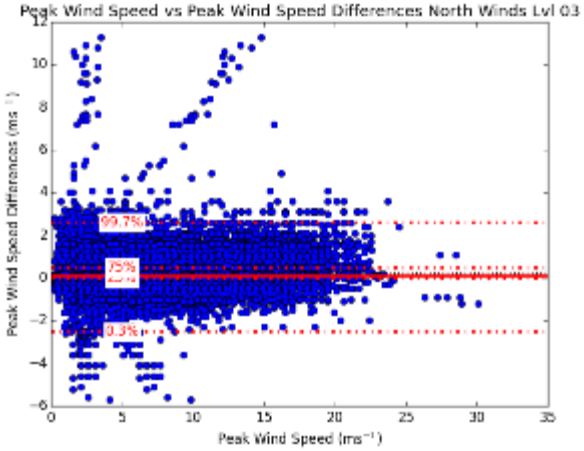
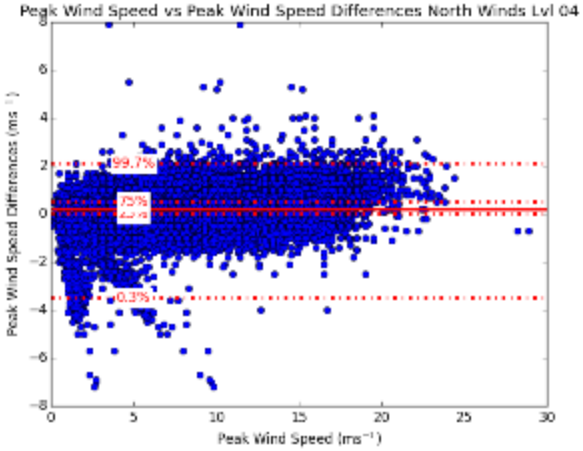
Northerly Winds - T1 & T2
350º - 10º









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Results

	T	Td	WS	WD	PWS	PWD	RH
Time Stamps	2276280	2276280	2276280	2276280	2276280	2276280	2276280
# of Sensors	12	12	12	12	12	12	12
# of Potential Observations	27315360	27315360	27315360	27315360	27315360	27315360	27315360
# Missing	16874872	17672268	18478961	18375500	18259066	17773728	16926322
% Missing	61.8	64.7	67.7	67.3	66.8	65.1	62.0
# Available	10440488	9643092	8836399	8939860	9056294	9541632	10389038
% Available	38.2	35.3	32.3	32.7	33.2	34.9	38.0

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Results

		T	Td	WS	WD	PWS	PWD	RH
	# Available	10440488	9643092	8836399	8939860	9056294	9541632	10389038
Unrealistic Data Check	# Removed	2812	1178	305883	409344	525778	1011116	747124
	% Removed	0.03	0.0	3.5	4.6	5.8	10.6	7.2
Conflicting with Tower	# Removed	0	0	1496	1496	1496	1496	0
	% Removed	0.00	0.00	0.02	0.02	0.02	0.02	0.00
Temporal Consistency Check	# Removed	0	0	0	0	0	0	0
	% Removed	0	0	0	0	0	0	0
Data Hang-Up Check	# Removed	83776	159995	11247	11247	11247	11247	159995
	% Removed	0.8	1.7	0.1	0.1	0.1	0.1	1.5
Climatological Check	# Removed	3134	14697	2	2	2	2	14697
	% Removed	0.03	0.2	0.00	0.00	0.00	0.00	0.1
Direct Sensor Comparison Check	# Removed	2752	30314	106826	106826	106826	106826	30314
	% Removed	0.0	0.3	1.2	1.2	1.2	1.1	0.3
Vertical Consistency Check	# Removed	370	222	0	0	0	0	222
	% Removed	0.00	0.00	0	0	0	0	0.00
Total Removed	# Removed	92844	206406	425454	528915	645349	1130687	952352
	% Removed	0.9	2.1	4.8	5.9	7.1	11.9	9.2
Toal Available	# Available	10347644	9436686	8410945	8410945	8410945	8410945	9436686
	% Available	99.1	97.9	95.2	94.1	92.9	88.1	90.8

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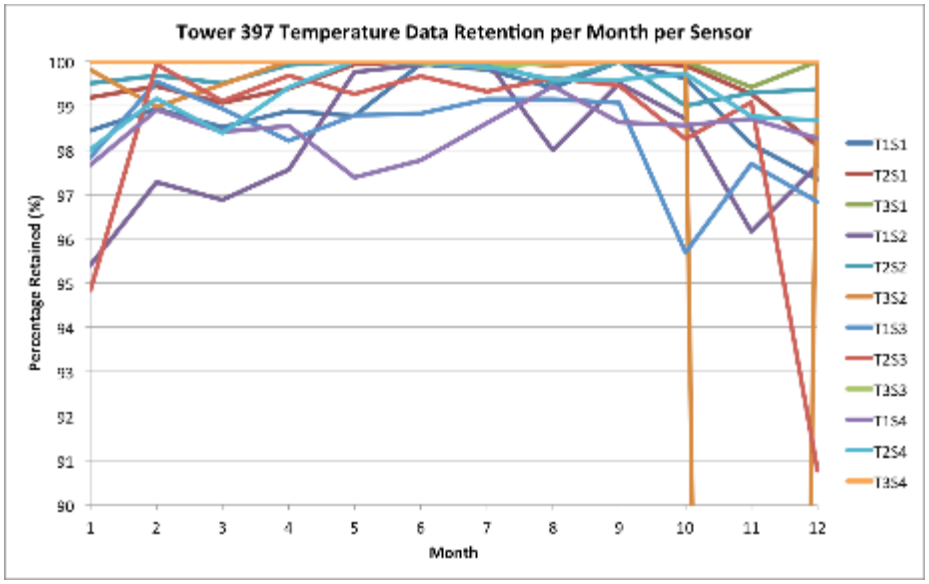

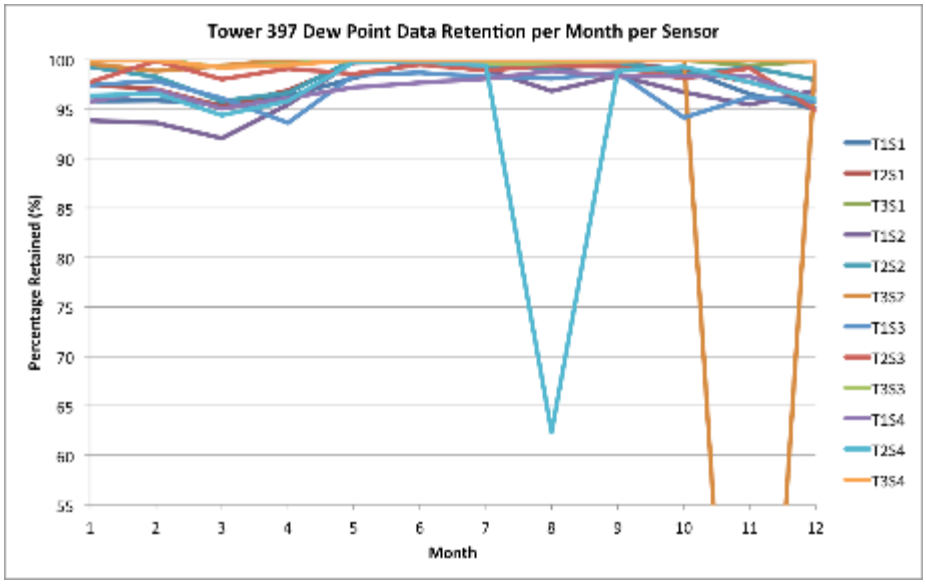

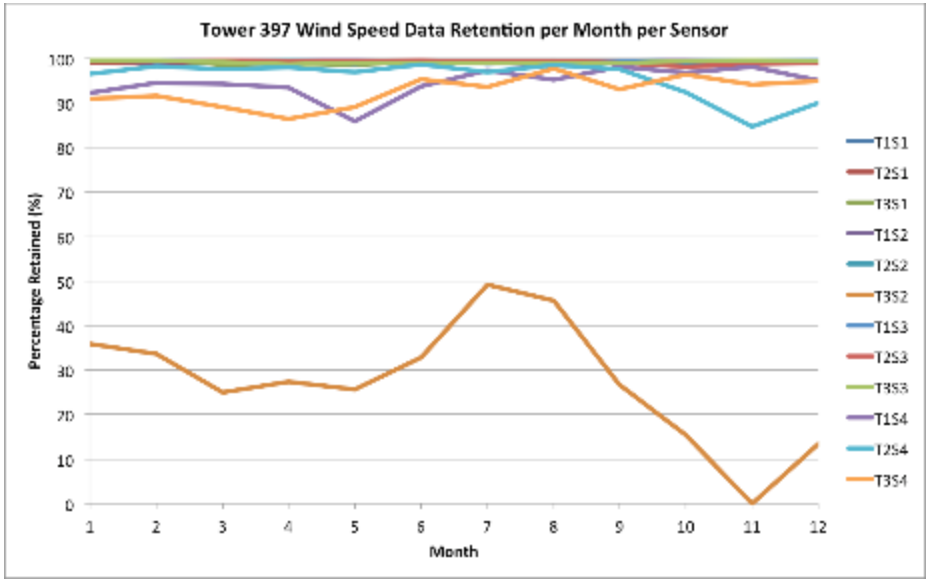

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Results – Up-Wind Tower

		T	Td	WS	WD	PWS	PWD	RH
Shear Check	# Available	3880550	3634361	2415216	2415216	2415216	2415216	3634361
	# Removed	0	0	5139	5139	5139	5139	0
	% Removed	0	0	0.2	0.2	0.2	0.2	0
	# Remaining	3880550	3634361	2410077	2410077	2410077	2410077	2410077

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